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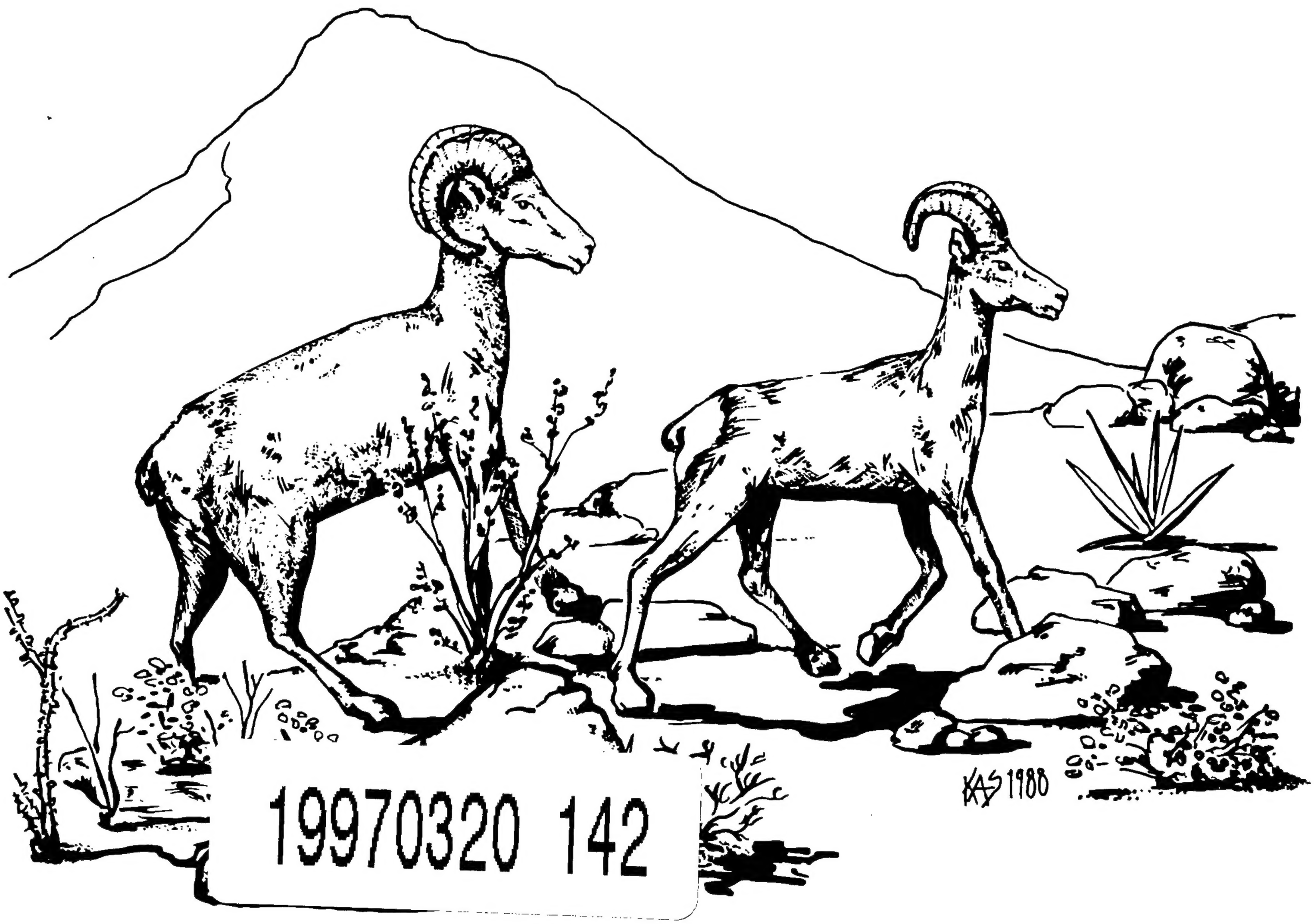
DESERT BIGHORN SHEEP: A GUIDE TO SELECTED MANAGEMENT PRACTICES



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Desert Bighorn Sheep:

A Guide to Selected Management Practices

A Literature Review and Synthesis Including Appendixes on Assessing Condition, Collecting Blood, Determining Age, Constructing Water Catchments, and Evaluating Bighorn Range

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Foreword

Perhaps no other ungulate has so many societies specifically dedicated to its preservation and management as does the bighorn sheep. Many of these are yet more specific in that they emphasize the bighorn sheep of the Southwest, the desert bighorn. Concern for desert bighorns is manifest in both State and Federal efforts in their management and conservation. In particular, because the majority of these animals are on Federal lands, not only are several Federal agencies as well as the States involved in management, but also involved are the many citizens who make use of these same lands for recreation, mineral extraction, and other 20th century activities. Management for the desert bighorn is of particular importance on several National Wildlife Refuges managed by the U.S. Fish and Wildlife Service: Cabeza Prieta, Havasu, Imperial, and Kofa National Wildlife Refuges, Arizona; San Andres National Wildlife Refuge, New Mexico; and Desert National Wildlife Range, Nevada.

The Office of Information Transfer, in one of its regular queries of management personnel regarding their current information needs, received a request from the Assistant Regional Director—Refuges and Wildlife in Albuquerque, NM (Region 2) and his Refuge supervisory and station staff in New Mexico and Arizona for assistance in pulling together some disparate information on desert bighorns that could simultaneously serve several purposes. These included: (1) a comprehensive review of portions of the literature on desert bighorn sheep; (2) a synthesis of current literature on selected topics; and (3) a discussion of what were judged to be priority management and research needs for desert bighorn sheep based on the results of this literature review and synthesis. The expected values of this exercise were likewise threefold: (1) a view of the situation from the perspective of persons outside the current management and research community would be obtained; (2) ideas useful for consideration by those planning both current and future management and research would be listed; and (3) a concise document useful as an orientation package to several important desert bighorn sheep management issues would be available for use in the Southwest.

This *Biological Report* addresses four topics selected by the staff of Region 2 as important and continuing concerns for desert bighorn sheep managers: water requirements of the species; effects of human activity on desert bighorns; desert bighorn disease and its control; and interspecific relations of bighorns and other desert ungulates. In addition, four appendixes reviewing data gathering procedures and specific management for bighorn sheep populations and their habitat are provided.

The intent throughout was to provide a succinct synthesis and to provide entry to the now substantial literature on the species. This document is an excellent starting point for review of desert bighorn management issues, and is another view of four desert bighorn management concerns that will prove useful in management and research planning for the species.

Ronald E. Kirby
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Research and Development

Preface

The desert bighorn sheep has been studied for many years and these studies have solved many management problems. Research has also identified the need for additional solutions to new or anticipated problems. This guide addresses some recent management practices and problems, suggests some techniques, discusses possible solutions, and identifies topics for further research.

The scope of the guide includes a review of water requirements of desert bighorn sheep, the effects of man's activities and disease on desert bighorns, and the interspecific relations of sheep and other animals. Identification of needed information is an important part of this guide. Our recommendations do not cover all of the research needed, but identify some of the most pressing needs.

Permission to include copyrighted material in this paper was obtained from V. Geist, H. E. McCutchen, and the University of Arizona Press. The cover illustration was drawn from an original photograph by N. S. Smith.

Summary

This guide summarizes pertinent literature on four topics of desert bighorn sheep ecology and management: (1) their water requirements and adaptations are compared with those of other desert-dwelling ungulates; (2) the effects of human activities such as mining, poaching, hunting, ranching, hiking, and urban encroachment are discussed; (3) diseases and disease control, specifically scabies and desert bighorn chronic sinusitis, are reviewed; and (4) the relation of bighorn sheep to other resident wildlife is addressed. Recommendations for management and research are included in each section. Finally, appendixes provide information on how to assess physical condition, collect blood, classify the age of sheep, construct water catchments, and sample vegetation.

Contents

Acknowledgments

Our gratitude is owed to the many naturalists, biologists, and wildlife managers who compiled information and published that wisdom. A. V. Sandoval gave us valuable information not yet published. H. E. McCutchen, V. Geist, and the University of Arizona Press are thanked for providing permission to use copyrighted material. We also thank Valery Catt for typing the manuscript.

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Introduction

Desert bighorn sheep (*Ovis canadensis cremnobates, O. c. mexicana, O. c. nelsoni, O. c. weemsi*) are important and highly desirable desert ungulates. The emotions elicited by these sheep in desert bighorn hunters, natural historians, biologists, recreationists, and politicians are probably only surpassed by those arising from the controversies over coyotes (*Canis latrans*). Large sums of money, time, and effort are expended to manage, study, preserve, hunt, and enjoy these animals. Despite the best intentions and efforts of State and Federal agencies, universities, and private organizations, there remain many unanswered questions and unresolved management problems concerning desert bighorns. Our intent in this guide is to summarize and synthesize what is known about several aspects of desert bighorn ecology and management. In particular, we address water requirements of the species, effects of human activity, disease, and interspecific relations. Where appropriate, we note which topics need additional research and we make recommendations for management. In several appendixes, we provide information that may be used to gather data necessary for making management decisions.

Taxonomy and Distribution

Bighorn sheep are in the Order Artiodactyla, Family Bovidae. There are six existing subspecies of *Ovis canadensis*: *O. c. californiana, O. c. canadensis, O. c. cremnobates, O. c. mexicana, O. c. nelsoni*, and *O. c. weemsi*. Desert bighorn sheep include the four subspecies that typically inhabit dry and barren mountain ranges: *cremnobates, mexicana, nelsoni*, and *weemsi*. However, sheep in the southern portions of the range of *californiana* and *canadensis* may also be considered desert bighorn because their habitat is dry and barren (Manville 1980).

Historically, about one million desert bighorn sheep inhabited the desert mountain ranges of the southwestern United States (Buechner 1960; Cooperrider 1985). However, habitat alteration and destruction by man have eliminated or reduced herds to the point that fewer than 12,000 desert bighorn sheep exist in isolated populations scattered throughout their former range (Monson 1980). The subspecies of desert bighorn sheep are distributed throughout the Southwest (Figure 1). Reintroduction programs have increased the current range of the desert bighorn in Arizona, California, Colorado, Nevada, New Mexico, Texas, and Utah (Weaver 1986).

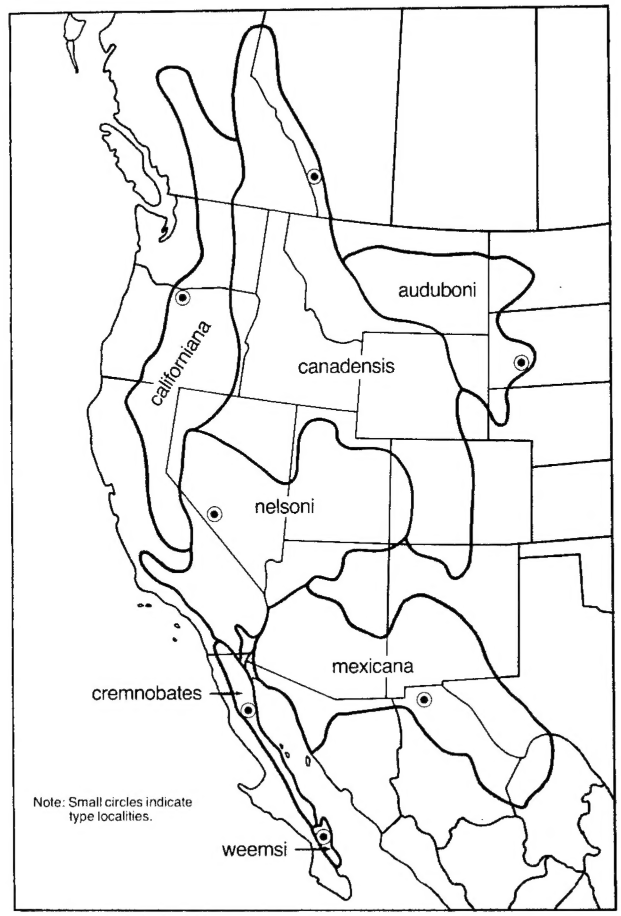

Figure 1. Approximate distribution of races of bighorn sheep. Desert bighorn sheep include *weemsi, cremnobates, mexicana, nelsoni*, and southern portions of the range of *californiana* and *canadensis*. The Audubon bighorn (*O. c. auduboni*) is extinct. The small *circles* indicate type localities. (Reprinted by permission from the University of Arizona Press, Tucson *in* G. Monson and L. Sumner, eds. The desert bighorn. University of Arizona Press, Tucson.)

Description

Large, recurving horns are a distinguishing feature of bighorn sheep. Horns of adult males are massive and curled forward beside the face and, together with the skull may represent over 10% of total body mass (Blood et al. 1970; Geist 1971). Females also have horns, but theirs are not as large or curved as those of males. Horns of males are as long as 305 mm (Wishart 1978). Desert bighorn sheep have smaller body sizes than other mountain sheep, but they have the largest horns. Adult males are 76–100 cm at the shoulders, about 150 cm long, and weigh about 70–91 kg. Females are smaller than males and weigh about 50 kg. Color varies between reddish brown and dark chocolate, and desert sheep usually have a white muzzle, rump patch, posterior of legs and belly. There is no neck ruff (Shackleton 1985). Adult females in their prime are well-proportioned, have an erect head, and a rounded rump and pelvic region. Prime males have a thick, blocky appearance,

and are too heavy in body to be considered well-proportioned (Hansen 1980).

Habitat

Desert bighorn habitat is usually rough, rocky, and broken by canyons and washes (Hansen 1980). Components of bighorn habitat include forage, escape cover, bedding areas, lambing and rutting areas, thermal cover, and water (Hansen 1980; Krausman and Leopold 1986). Vegetative communities used by desert sheep range from upland pinyon (*Pinus edulis*)-juniper (*Juniperus* spp.) (Browning and Monson 1980) to desert scrub (e.g., creosotebush [*Larrea tridentata*]-ragweed [*Ambrosia* spp.] communities).

Ecology

Reproduction

Desert bighorn sheep are promiscuous. Males and females are sexually mature at 18 mo, although females usually do not breed until they are 2.5 yr old (Wishart 1978). The gestation period is 175–180 d (Wishart 1978; Turner and Hansen 1980). Copulation usually occurs between July and December, and lambs are born from January through June. Lambing and breeding dates vary by location.

Weights of captive lambs at birth are 2.8–5.5 kg (Blunt et al. 1977; Geist 1971; Hansen and Deming 1980). Lambs are usually weaned at 4–6 mo (Geist 1971).

The bighorn sheep exhibits a wide spectrum of social behavior patterns and is one of the most socially active North American ungulates (Shackleton 1985). Bighorn sheep live in groups, but for most of the year adult males usually live apart from females and young (Geist 1971). Male and maternal groups often occupy separate home ranges. Group size varies (n = 2–9) with season and among populations (Blood 1963; Chilelli and Krausman 1981). Males associate with maternal groups during rut. During the rest of the year males are not excluded but leave maternal groups to join male groups, where they then become physically and socially dominant to adult females (Geist 1971). Social status of males is founded on horn size and fighting ability (Geist 1971).

Maintenance and comfort behavior includes stretching, shaking, rubbing, scratching, urinating, and defecating. Females squat to urinate; males stand; and all sheep stand during defecation (Shackleton 1985).

Desert bighorn sheep are active throughout the day although most activity is diurnal (Chilelli and Krausman 1981; Krausman et al. 1985; Alderman et al. 1988). Daily activity patterns consist of alternate feeding and rest-rumination bouts (Chilelli and Krausman 1981; Alderman et al. 1988). Feeding is concentrated near dawn and dusk but varies depending on habitat quality, energy requirements, physiological condition, and social organization (Eccles 1981).

Social-behavior patterns in bighorn sheep are important (Geist 1971) and develop as sheep mature (2–3 yr for females; 6–7 yr for males). Learning is important for dominance relations among males because males recognize other individuals and develop social status by viewing horns of other males (Geist 1971).

Food

Desert bighorn sheep are adaptable foragers; their diet is related to the habitat occupied. Generally, desert bighorn sheep consume grass when available. When grasses become limited, browse and forbs assume greater importance (Brown et al. 1977; Browning and Monson 1980). Minerals are obtained from natural salt-licks or from artificial blocks provided by game managers. Desert bighorns can exist on ranges without freestanding water (Krausman et al. 1985; Alderman et al. 1988), but most populations have access to surface water.

Mortality Factors

Parasites, disease, competition, predation, accidents, mineral and dietary deficiencies, and abnormal climatic conditions contribute to mortality of desert bighorn sheep. The nematode lungworm (*Protostrongylus stilesi*) that has influenced northern subspecies of bighorn sheep has not affected desert bighorn sheep (Allen 1980). However, desert subspecies are susceptible to a variety of bacterial and parasitic infestations (e.g., *Escherichia coli, Pasteurella* spp., *Corynebacterium* spp.). Numerous parasites infest desert bighorn sheep (e.g., *Oestrus ovis*, which has been implicated with desert bighorn chronic sinusitis).

Competition contributes to mortality when limited habitat is used by other grazing ungulates (Wishart 1978). The carrying capacity of bighorn habitat can be reduced due to resource competition among bighorn herds and other large ungulates (e.g., burros [*Equus asinus*], desert mule deer [*Odocoileus hemionus crooki*], and livestock; Wishart 1978; Krausman and Leopold 1986). The negative effects of domestic livestock on desert bighorn sheep are well documented (see Disease and Its Control and Interspecific Relations sections). Desert bighorn sheep are preyed on by coyotes, mountain lions (*Felis concolor*), bobcats (*Lynx rufus*), eagles (*Haliaeetus leucocephalus* and *Aquila chrysaetos*) (Wishart 1978; Kelly 1980), gray fox (*Urocyon cinereoargenteus*), jaguar (*Panthera onca*), and ocelot (*Felis pardalis*). Predation is limited due to the precarious habitats desert sheep use; however, that same habitat contributes to mortality from falls (Wishart 1978; Allen 1980). Other reported accidents include being trapped in dry waterholes, fights between males, lightning strikes, and road kills. Inbreeding may contribute to mortality in isolated, small populations that characterize many desert bighorn populations.

Management

Management of desert bighorn sheep has evolved through three phases: (1) a custodial phase characterized by restricting hunting and establishing refuges; (2) obtaining better inventories and experimentation with water developments and animal handling; and (3) opening limited hunting (Weaver 1986). An additional phase would be the reestablishment of bighorn sheep throughout their historic range. Most States are actively reestablishing herds of sheep on ranges from which they have been eliminated. Additional management efforts focus on forage improvement (e.g., burning, chaining, use of herbicides), reduction of competition and habitat improvement (i.e., water developments; Graf 1980).

Water Requirements

All desert animals need water. The adaptations of desert species to obtain, use, and conserve water may be anatomical, physiological, behavioral, or some combination of the three. Anatomical modifications associated with successful desert mammals include: color or pattern of colors of the coat; density of hair; shape of body or extremities; kidney structure; carotid artery location and association with a cooled venous network from the nasal area; and length of the water reabsorptive portion of the large intestine.

Physiological adaptations include: methods of concentrating urine; extracting water from feces; extracting preformed water from food; producing metabolic water by the oxidation of fats and carbohydrates; dehydration tolerance; fluctuation of body temperature; differential regulation of body and brain temperatures; and lowering of metabolism. Behavioral activities that allow mammals to occupy hostile desert environments include: avoiding heat by nocturnal or crepuscular activity; seeking coolest or most humid shelters; seasonal migration or daily movements to seek water or avoid drought; diet selection for succulent food or plants that have absorbed moisture or are dew-laden at night; and orientation of body relative to the sun's rays.

The major method by which large mammals regulate body temperature—evaporative cooling—requires water, and a large part of the water lost by mammals is for this use. Consequently, when discussing water requirements of desert bighorns we must consider how they regulate their body temperature. (For a review of desert adaptations see: Schmidt-Nielson [1964]; Taylor 1969; Maloiy [1972].)

In this section we summarize the literature on the water requirements of desert bighorn sheep and how they cope with water scarcity. We also note how some other desert ungulates are adapted to water scarcity and compare the desert bighorn's capabilities to those of other species.

Anatomical Adaptations

The desert bighorn lacks the obvious modifications of many desert mammals for life in an arid environment. For example, light-colored coats reflect more radiation from the sun or from the ground than do darker-colored coats; many desert ungulates are very light-colored or even white. Coat color of the desert bighorn, however, varies from blackish to medium gray-brown (Hansen 1980).

The shape of desert bighorn extremities does not represent typical desert adaptation, nor does its general body conformation. Further, compared to successful ungulates of extreme desert habitats, the desert bighorn's internal structures, such as the kidney, are not significantly modified to concentrate urine (Horst 1971; Horst and Longworthy 1971). Other internal structure adaptations have not been investigated in the desert bighorn.

Another adaptation of many ungulates to arid, hot environments is the lack of fat reserves. Subcutaneous fat hinders the dissipation of metabolic heat and probably evolved in response to cold environments and as a method of storing reserves. Even when in excellent condition, the Grant's gazelle (*Gazella granti*), oryx (*Oryx gazella*), and gerenuk (*Litocranius walleri*) have very little subcutaneous fat (Ledger et al. 1967); in contrast, desert bighorns store substantial amounts (Hansen 1980).

Physiological Adaptations

The ability to allow body temperature to rise a few degrees during the day without panting and to lose that accumulated heat when the ambient temperatures drop at night is shared by many desert ungulates (Schmidt-Neilsen 1964; Taylor 1970, 1972). Alternatively, some animals decrease body temperatures during the night, a process which allows them to store more heat the next day. No studies on the desert bighorn have indicated that their body temperatures fluctuate significantly in relation to ambient diel temperatures.

Lowering the metabolic rate minimizes heat production, and water for cooling is conserved. This mechanism, also, is not known to be used by the desert bighorn.

The ability to extract water from feces was reported by Turner (1970) to be nearly as great in desert bighorns as in the camel (*Camelus dromedarius*). Turner also stated that desert bighorns obtain little preformed water from their food and that metabolic water probably contributes little to their overall water needs. Water ingested with food contributes to the overall intake of water, but during critical dry seasons, some succulent plants may also be dehydrated. This means that the amount of water required to void the electrolytes obtained from the plants may exceed the amount of water gained (Turner 1973; Turner and Weaver 1980).

Because neither the ability of desert bighorns to concentrate urine nor their tolerance to total dissolved solids in water is known, the question of how much preformed water they can obtain from drought-stressed plants remains unanswered.

Behavioral Adaptations

During the early part of the dry season, pricklypear (*Opuntia* spp.), pincushion cactus (*Mammillaria* spp.), and barrel cactus (*Echinocactus* spp.) may contain enough water to supplement free water ingested (Russo 1956; Simmons 1964; Krausman et al. 1985). Diet of desert bighorns in the Big Hatchet Mountains, NM, was 53% pricklypear in June, suggesting an increased consumption of it as an adaptation to a waterless range (Watts 1979). Turner (1973) concluded that sheep did not use freestanding water when forage contained 15–30 mL water/gram dry weight.

On several ranges, bighorn sheep remain within 1.2–4.8 km of permanent water sources (Gross 1960; Blong and Pollard 1968; Turner 1973). Koplin (1960) noted that bighorn sheep may migrate to higher elevations and cooler temperatures to reduce water loss from evaporative cooling. A male and female desert bighorn in Utah reduced their home range size during summer months because of limited water availability (Wilson 1971). Leslie (1977) found that males frequented water sites more often during the breeding season. Campbell and Remington (1979) found that 54% of the sheep in the Buckskin Mountain, AZ, range drank between dawn and 0800 h in June and 75% drank during that time in July. Koplin (1960) concluded that a minimum of 82.5% of all drinking on the Desert Game Range (now Desert National Wildlife Range), NV, occurs during daylight, with the greatest activity just before sunrise (17.6%) and at 1200 h (19.7%). Turner and Weaver (1980) suggest that for sheep to drink in early mornings is energetically efficient behavior that reduces unnecessary heat gain.

The frequency of drinking has been reported by many authors and has been associated with season, temperature, days since last precipitation, and forage moisture. Drinking frequencies vary—from 1 to 5 d when temperatures are high and forage water is low, to total independence of free water on some ranges (Graves 1961; Welles and Welles 1961; Campbell and Remington 1979; Turner and Weaver 1980).

The literature is replete with references to bighorn populations that are able to survive without freestanding water for months or even throughout the year. Monson (1958) observed sheep that did not drink water for 6 mo beginning 1 July on Cabeza Prieta Game Range (now National Wildlife Refuge), AZ. Valverde (1976) reported that sheep on some Sonoran ranges do not drink. Krausman et al. (1985) monitored two radio-collared ewes for 10 d: During 239 h they did not drink water, although the ambient temperature exceeded their presumed body temperature 33% of the time.

In captivity, adult female and male desert bighorns consumed 6.4–12.7 and 3.0–18.7 L of water per day, respectively (Turner 1970, 1973; Koplin 1960). Turner and Weaver (1980) reported that a group of desert bighorns they observed in the wild drank water in amounts of 20%–30% of the estimated body weights. From these observations and from observations on penned animals, they estimated that desert bighorns must drink a minimum of 4% of body weight per day during the summer.

Although water requirements of desert bighorns are not completely understood, they are apparently able to modify their activities to cope with environmental stresses. Unfortunately, the paucity of basic water physiology, metabolic, and anatomical information leads to conflicting conclusions about many aspects of desert bighorn ecology. As a case in point, a series of recent articles has discussed the possibility that the desert bighorn is a relict from more mesic environments and is thus maladapted to desert habitats (Bailey 1980; McCutchen 1981; Hansen 1982; Wehausen 1984; Geist 1985). Authors have developed arguments on both sides of this issue, arguments which appear to be based on preliminary and perhaps inadequate studies.

Management Recommendations

Although much remains to be learned about water requirements of desert bighorn sheep, general recommendations can be made to manage water quality and availability for them. Water should be clean and distributed throughout the ranges (every 3–5 km) such that a source of water will be within the weekly area of activity of sheep. Water should be within 0.5 km of escape terrain with no dense, tall vegetation in or around the water, because sheep avoid areas not affording ample visibility (Leslie and Douglas 1979; Hansen 1980; Turner and Weaver 1980).

When water sources have to be created, they should be planned to decrease conflict between desert bighorns, other ungulates, and people. By attracting other ungulates to an area of limited resources, adding water may increase competition, cause overgrazing, transfer parasites or disease between bighorns and native or domestic ungulates (Bunch et al. 1978a), or cause fouling of water with feces (Welles and Welles 1961; Wilson 1977). Krausman et al. (1985) and Krausman and Leopold (1986) expressed concern over the development of water in less than optimal habitats where water has not been demonstrated to be a limiting factor. Sheep may have existed on such ranges for thousands of years without free water and, although densities are low, their number may be within the constraints of available resources. Before adding water in sheep habitat, the need for water should be

established. If annual plant biomass has been measured and is adequate (suggesting that food is not a limiting factor), water should be supplied temporarily in mobile tanks before building more permanent water developments.

Research Recommendations

The lack of answers to many basic questions about the physiology and anatomy of desert bighorns inhibits successful management. These answers are needed, but evaluation of current and planned management techniques is necessary. We know that when agencies provide water to arid ranges, desert bighorn sheep use it; nevertheless, we need to study the effect of freestanding water on reproduction and survival to breeding age of both sexes. The information on survival should be synthesized with results of studies on competition, disease, stress, and the effect of human disturbance.

Sufficient information from descriptive studies is available; now, experimental research is justified and needed. Studies that manipulate water availability and provide measures of the management end product – more or healthier desert bighorns – should be a priority.

Effects of Human Activity on Desert Bighorn Sheep

Man's activity in bighorn sheep habitat has altered sheep behavior and populations. Human disturbance at watering sites has created shifts in drinking behavior (Leslie and Douglas 1980; Campbell and Remington 1979) which may affect lamb survival (Leslie and Douglas 1980). Vehicle use and related human activity has reduced sheep use of areas around water by 50% (Jorgensen 1974). The recreational demands on bighorn sheep habitat include picnicking, camping, exploring, hiking, hunting, rock-hounding, and desert dwelling, any of which can destroy bighorn sheep cover and water. How sheep respond to these pressures varies (Nelson 1966). DeForge (1972) demonstrated that road traffic can negatively influence sheep populations, but recreational use of trails is not necessarily detrimental (Hicks and Elder 1979; Hamilton et al. 1982). Purdy and Shaw (1981) reported that sheep are not influenced by most hiking activity, but some activities (hunting, hiking and camping, vehicle traffic) may not be compatible with sheep.

Some of man's uses of sheep habitat – mining, poaching, hunting, ranching, fence construction, and urbanization – are detrimental to sheep (Duncan 1960; Follows 1969; Helvie 1971; Ferrier 1974; Krausman et al. 1979; Gionfriddo and Krausman 1986). Combinations of these activities may cause sheep to restrict their use of quality habitat or to form smaller groups resulting in fewer sheep per unit of habitat.

Human–sheep interactions are difficult to evaluate because man's activities in sheep habitat are so varied. How an individual disturbs one or more sheep is a complex question – the disturbance may be planned or impulsive, intentional or unintentional, purposeful or irrational, obvious or barely noticeable. Anyone is capable of disturbing sheep at any time, and the results may be insignificant or catastrophic. It is important that managers of sheep habitat and populations be able to identify potential problems and efficiently eliminate them. For example, if critical habitats at certain seasons are suspected of being influenced by man, the public should be informed of the problem and entry to the areas restricted. Although people can be detrimental to bighorn sheep populations unintentionally, an informed public may be the solution to some human–sheep interaction problems.

Examples of Management Restrictions

Limited Access to Kofa

Bighorn sheep exist on ranges today because of management decisions. If their survival is important, but impaired by man's activity, human activities will have to be restricted. The success of the bighorn sheep program on the Kofa National Wildlife Refuge, operated by the U.S. Fish and Wildlife Service in western Arizona, is a direct result of setting priorities for the success of the sheep population. Access to the range is limited, and sheep are protected from habitat alteration. Sheep from this population have been transplanted throughout the southwestern United States, and the hunting opportunities on the Refuge are of the highest quality.

Santa Catalina Mountains and Dog Control

Geist (1975) argued that potentially consumptive and nonconsumptive uses of sheep can be detrimental to any given population of sheep. Results can be disastrous if development is added, as exemplified by the sheep population in the Santa Catalina Mountains outside of Tucson, AZ. The city has grown to border the western and southern edges of sheep habitat on the Pusch Ridge Wilderness (southwestern corner of the Santa Catalina Mountains in the Coronado National Forest). As parks, business parks, housing developments, hotels, and recreational trails continue to be developed on the edge of and into sheep habitat, the future of sheep on the range becomes problematic. There are very few, if any, restrictions on human use of this sheep habitat, and residents of Tucson use the mountain for numerous recreational activities.

In the early 1980's, the Pusch Ridge Wilderness received more than 34,000 recreational visitors annually (Purdy and Shaw 1981). This number will undoubtedly increase as Tucson continues to grow, but it is not clear if the increased number inundating sheep habitat will be

controlled. Survey respondents, faced with a hypothetically declining sheep population in this habitat, favored mandatory restrictions on recreational use in specified areas during critical seasons (Purdy and Shaw 1981). However, it is never certain whether such restrictions, if implemented, would be heeded. Hicks and Elder (1979) reported that 66% of 35 groups of hikers they interviewed in California's Sierra Nevada Mountains stated they had engaged in some form of prohibited off-trail activity.

In the Pusch Ridge Wilderness, where only 8% of those surveyed have claimed ever to have seen sheep (Purdy and Shaw 1981), it may be difficult to convince recreationists of the need to impose and obey use restrictions. One such negative example exists: The U.S. Forest Service has tried in vain to enforce leash restrictions for pets in this area since 1984. On 11 August 1986, bighorn sheep habitat in the Pusch Ridge Wilderness was effectively closed to dogs by Federal regulation—dogs on leashes were allowed on the trails forming the perimeter of the closed area, but the heart of the bighorn habitat was declared off-limits to dogs. Violations of the restriction are punishable by a fine of not more than $500 or imprisonment for not more than 6 mo or both, but compliance has been low and the regulations thus ineffective. It may prove impossible to implement and enforce other restrictions necessary to protect the remaining sheep on the Wilderness.

Unfortunately, the Pusch Ridge Wilderness population of bighorn sheep will thus face a critical test of its ability to withstand human encroachment. Although some sheep may become habituated to common human-related stimuli (Hicks and Elder 1979), others may temporarily or permanently abandon areas frequented by man (Dunaway 1971; Campbell and Remington 1979). Unfortunately, all indications are that this population will respond negatively to man's development unless rigid restrictions on access and use are made and strictly enforced.

Management Recommendations

Managers should be aware of human activities that have caused a direct decline of sheep elsewhere and should be familiar with specific conditions in sheep ranges under their management that may result in human–sheep conflict. These conflicts can be identified and resolved by long-term monitoring and appropriate management actions. These actions largely involve restriction of the quantity, type, and timing of human activity on sheep range. Whenever restrictions are imposed, it is important that the population affected be informed why restrictions are necessary. Laws are only enforceable if they are respected by both the public and enforcement personnel.

Information on how man's recreational pursuits influence bighorn sheep is limited. Whenever man and bighorn sheep regularly share the same range, every effort should be made to determine how human activity affects the bighorn sheep population. Management's best response is to be constantly aware of actual or potential detrimental human activities.

Disease and its Control

Desert bighorn sheep are susceptible to many diseases and parasites. Bacterial pneumonia (*Pasteurella* spp., *Staphylococcus* spp., *Corynebacterium* spp.), chronic sinusitis, para-influenza-3, bluetongue, epizootic hemorrhagic disease, and contagious ecthyma are among diseases that afflict desert bighorns (Hailey et al. 1972; Bunch 1979; De Forge et al. 1981; Allen and Bunch 1982; Turner and Payson 1982). Important parasites include lungworms, *Protostrongylus stilesi* (Allen 1971) and *Muellerius capillaris* (Russi and Monroe 1976); scabies mites, *Psoroptes cervinus* and *P. ovis* (Cater 1968; Decker 1970; Bunch et al. 1978a,b,c; de Vos et al. 1980); and the bot fly, *Oestrus ovis* (Bunch et al. 1978a,b). Numerous tapeworms, nematodes, ticks, and fleas also infest desert bighorns but are less debilitating than the other parasites mentioned. Indirectly, ectoparasites may be important vectors for disease-causing organisms. Allen (1980) summarized diseases and parasites and their relative importance to desert bighorns, and Krausman et al. (1984) updated the literature on this subject in their annotated bibliography.

Diseases of any wild population are difficult to treat. Consequently, the twofold goal of management should be prevention of conditions that promote dangerous diseases and early detection of diseases. Once a serious disease is firmly established, only herculean efforts may prevent substantial losses. In this section, we discuss procedures to control disease in desert bighorn sheep, suggest prophylaxis or treatment, and identify research needs.

A Perspective for Disease Evaluation

Disease organisms may normally be present in the environment of a bighorn sheep population but cause little damage if the animals are in good physical condition. Inadequate forage quantity or quality, inclement weather, exposure to livestock, and other stressful events can predispose individual sheep to disease (Allen 1980). Geist (1985) suggested that the small size of desert bighorns may be evidence that they are suffering chronic shortages of nutrients. Evans (1978) emphasized that for domestic animals, maintaining health is a positive approach and is more efficient than merely preventing disease—this statement could also apply to wild animals.

Diseases to which bighorns have not previously been exposed may spread rapidly through a population—domestic or feral animals may introduce exotic diseases or parasites; wild animals that extend

their range because of natural or man-induced environmental change may introduce diseases to which bighorns have not acquired immunity; introducing desert bighorn sheep into areas where other ungulates exist may subject the sheep to diseases to which they are not immune. Although current indications are that this latter problem remains only a potential threat to desert bighorns, examples of this situation for other species are numerous, including the transfer of arterial worms (*Elaeophora schneideri*) from deer to elk (Hibler and Adcock 1971; Worley 1975) and meningeal worms (*Pneumostrongylus tenuis*) from white-tailed deer (*Odocoileus virginianus*) to other North American cervids (Eckroade et al. 1970; Prestwood 1970).

Recent Disease Problems

Scabies

In 1978, five rams shot in the San Andres National Wildlife Refuge were noted to have psoroptic mites and scabies lesions. The next year, the number of sheep observed on surveys dropped by more than 60%—from 200 to 70. Scabies was the suspected cause, even though no deaths attributable to scabies were documented (Lange et al. 1980; Sandoval 1980). The effects were already serious by the time the disease was discovered in the population. Prompt action to capture, enclose, and treat the remaining individuals saved a portion of the population. Forty-nine sheep were captured and dipped in a toxaphene solution; 34 sheep survived. Of the estimated 20–25 sheep remaining on the range, 19 were injected with ivermectin by way of a ballistic implant shot from a compressed-air rifle (Sandoval 1980). Although the ballistic implant still holds promise, it was unsuccessful in application, because absorption was hindered by a tissue reaction to the drug-carrying matrix, and because two doses of the dilute concentration of the drug were required. Twelve of the sheep moved after the mite outbreak were reintroduced in 1981 (Munoz 1981). These 12, and 13 of the remnant population, were radio-collared to track movements and monitor mortality (Munoz 1982). Even though Munoz (1982) saw no indication of scabies during 1981, Kinzer et al. (1983) reported that scabies infections continued in 1983. From 1981 to 1983, sheep that were captured were injected with invermectin with hand syringes. During 1984 captures, 18 sheep had clinical symptoms, and 8 had mites. In 1985, 7 of 14 captured sheep had clinical symptoms and all had mites (A. Sandoval, personal communication). The unsolved question remains—has an especially virulent strain of *Psoroptes ovis* evolved, or is this population especially susceptible to this parasite?

Desert Bighorn Chronic Sinusitis

Desert bighorn chronic sinusitis (DBCS) is thought to be caused by the bot fly which induces a bacterial infection within the frontal and cornual sinuses. Apparently, the larvae are deposited in the nasal passage and infect the host with a bacterium. DBCS is a serious mortality factor (Bunch et al. 1978a,b,c). Bunch and Webb (1979) examined 69 skulls and found 45% of the ewes and 22% of the rams had been infected. They thought that these figures were conservative estimates, because at Zion National Park, Utah, only 50% of the sheep that had DBCS actually exhibited skeletal lesions. Eight of 16 skulls that we examined from 1979 to 1986 from the Harquahala complex in Arizona had lesions, suggesting that this disease may be as serious a threat to bighorn sheep as Bunch et al. (1978c) indicated.

As an additional complication, Bunch and Allen (1981) reported that 20% of 630 bighorn skulls had bone anomalies that they believed were caused by pyogenic osteomyelitis. Bunch (1979) postulated that pyogenic osteomyelitis was evidence of chronic sinusitis and thought that nearly all populations surveyed in Arizona were affected. The infection in this disease is usually in the cornual sinus area. After an abscess forms over the brain case, the disease penetrates to the brain and eventually kills the animal. In captive animals, the disease is difficult to detect early in its course; early detection in wild animals is even more difficult.

Management Recommendations

Prevention of disease may best be accomplished by maintaining a healthy ecosystem. This requires that range conditions be as good as possible. Minimizing stresses from overcrowding, poor nutrition, drought, competition from other ungulates (native or introduced), harassment by humans during critical periods, and bisection or fragmentation of habitat provides a positive approach to disease control. This requires that monitoring of habitat variables be a priority. Detailed and systematic records on population size, composition, reproduction, and physical condition of desert bighorns as well as other ungulates should be obtained. Whenever opportunities to handle live or freshly-killed animals arise, maximum amounts of information should be gathered. Animals captured, for whatever purpose, should be examined; proper samples should be taken, and the material analyzed by trained personnel. Wehausen (1987) cautions that when a population is sampled for the presence or absence of a disease, only presence can be shown confidently. In order to state with confidence that prevalence of any disease in a population is 10% or less, prohibitively large sampling is necessary.

If desert bighorns are to be managed properly, every attempt should be made to anticipate problems rather than react to crises after they occur. Appendixes A and B contain information on techniques for collecting

samples and gathering appropriate data as suggested in this section.

Research Recommendations

In addition to ongoing monitoring of the health of wildlife populations, there are some basic questions that require answers. Why are certain populations periodically infected with scabies and other populations rarely infected? Are the apparent immunities caused by genetic differences or previous exposure, or are disease organisms more virulent in various areas? Are reintroduced sheep being subjected to a set of potential diseases to which they have had no previous exposure and, therefore, no acquired immunity? What diseases or vectors of disease organisms are maintained or spread by other native wildlife that are in contact with bighorn sheep? Are there ways to segregate various species of animals at water holes to minimize contact with the disease organisms they harbor? Would it be possible to control the incidence of bot fly-caused chronic sinusitis by using pesticides, releasing sterilized male flies into problem areas, or other biological controls? Could water hole construction be used to disperse concentrations of animals, thereby minimizing potential for contamination? Is water at concentration areas a source of infection, and could the water be treated? Is disease merely an indicator of unhealthy conditions induced by other causes?

To answer these questions, wildlife biologists should collaborate with scientists in other disciplines. Veterinarians, pathologists, entomologists, parasitologists, and ecologists are required to establish an effective team to provide answers.

Releasing desert bighorn sheep onto unoccupied ranges, developing water sources, and altering of habitats are management activities that may alter the dynamic equilibrium between desert bighorn sheep and disease organisms. Consequently, research into the relation of disease and parasites to these activities should have priority.

Interspecific Relations

Population dynamics of bighorn sheep can be affected by resident species of big and small game through competition, predation, and the transmission of diseases and parasites. Various relations exist between bighorn sheep and other species inhabiting a portion or all of the same range. However, literature from the Southwest indicates that, under usual conditions, bighorn sheep are not adversely affected by other wildlife species.

Competition

Game species which may be possible competitors of the desert bighorn include mule deer, collared peccary (*Tayassu tajacu*), black-tailed jack rabbits (*Lepus californicus*), white-winged doves (*Zenaida asiatica*), Gambel's quail (*Callipepla gambelii*), and chukars (*Alectoris chukar*). Competition between these species and bighorn sheep is mainly correlated with restricted water availability. Jones (1980) stated that mule deer and bighorn sheep habitats overlap at watering places, and where water is limited, competition may exist. On sheep range in the Desert National Wildlife Range, Nevada, competition was documented between sheep and mule deer (Jonez 1960). Halloran and Deming (1958) note that mule deer may be responsible for depleting water on many southwestern ranges. White-winged doves, Gambel's quail, and chukars have been reported to consume water to the detriment of sheep (Jones 1980; Welles 1965).

Competition between bighorn sheep and mule deer for forage may also exist; Jones (1954) stated that where terrain is not rugged, sheep may be forced to compete with deer for forage. Direct competition for key browse species may occur, especially during winter (Kennedy 1963). However, analysis of sheep and deer feces indicates that the diet differences (sheep – 65% grass species; deer – 77% browse species) are enough to prevent direct competition (Yoakum 1966). Buechner (1960) warned that the effect deer have on sheep numbers may be greater than overlapping diets indicate. Overlap between deer and sheep home ranges may cause vegetation to deteriorate, causing sheep, rather than deer, to decline because of the low reproductive rate of sheep.

Other wildlife also interact with desert sheep. Russo (1956) observed the presence of collared peccary on many sheep ranges but indicated that the extent of interspecific competition was unknown. Jones (1980) stated that diets of sheep and black-tailed jack rabbits overlap, but competition has not been documented between them.

Domestic and introduced species have a greater competitive effect on sheep than do resident species. The negative effects of Barbary sheep (*Ammotragus lervia*); wild burros; and domestic cattle (*Bos taurus*), sheep (*Ovis aries*), and goats (*Capra hircus*) on desert bighorns is well documented (Simpson et al. 1978). Barrett (1967) noted the potential threat of Barbary sheep to bighorn sheep, resulting from similar habitat and diet preferences. Lee (1960) suggested the possibility of transmission of disease and parasites to bighorn sheep by Barbary sheep. Seegmiller and Simpson (1979) warned that introduced Barbary sheep might compete with bighorn sheep and other members of the natural ecosystem.

Burros in bighorn sheep range create similar problems. Burros damaged sheep habitat in the Lower Colorado River Valley in Arizona and California (Hanley and Brady 1977) and in the Panamint Mountains, CA (Douglas and Norment 1977).

McMichael (1964) determined that an overlap between burros and bighorn sheep exists in forage consumption and summer ranges in the Black Mountains in Arizona. Seegmiller and Ohmart (1981) discussed the overlap of diet and habitat preferences between bighorn sheep and burros. Dunn and Douglas (1982) documented the decreased usage of watering sources by bighorn sheep when high numbers of burros are present in Death Valley National Monument, CA. Weaver (1959, 1973) discussed the effect burros have on the watering sources of bighorn sheep. The impact of domestic cattle, sheep, and goats on native populations of bighorn sheep is discussed by Jones (1980) and Gallizioli (1977).

Predation

Predation in the Southwest on bighorn sheep is common. However, it is not considered a serious threat to any population of bighorn sheep, and most predation is opportunistic (Kelly 1980). Predators of desert bighorn sheep include coyote, gray fox, bobcat, and mountain lion (Goldman 1961). Weaver (1961) stated that the coyote is the most common predator on sheep ranges, but that it is relatively unimportant in the population dynamics of bighorn sheep. McQuivey (1978) observed coyotes chasing and feeding upon sheep on several occasions. Simmons (1969) recorded 12 coyote interactions with sheep, noting that sheep seem to be most vulnerable around watering holes. Analysis of coyote scat indicates that sheep and deer occur relatively infrequently in coyote diets (Russo 1956; Simmons 1969). Predation by gray fox on sheep has been reported in the Plomosa and Mohawk mountains, Arizona (Nichol 1937). However, the actual effectiveness and frequency of predation by gray fox is unknown. Bobcat predation and consumption of bighorn sheep has been documented in the Southwest (Russo 1956; Groves 1957; Elliot 1961), but bobcats do not seriously threaten the populations of bighorn sheep in the Southwest. The mountain lion does not influence most sheep populations. Only small populations of mountain lions exist on established desert bighorn sheep ranges and have not been documented as a significant cause of mortality (Kelly 1980). Many single observations of mountain lion predation are recorded (Carson 1941; Gabrielson 1941; Cronemiller 1948; Cain et al. 1972).

Management Recommendations

Most studies that have evaluated interspecific relations between bighorn sheep and native wildlife have concluded that the relations are not detrimental to sheep. However, larger ungulates such as desert mule deer may seriously compete for forage and water. Managers should be aware that placing water in bighorn sheep habitat may also attract deer which could directly compete with sheep. Having evolved together, native wildlife species are usually compatible, but introduced animals and domestic livestock create serious problems. Usually, whenever burros and livestock share range with desert bighorns, problems develop: native sheep are eventually eliminated through diseases transmitted by domestic stock or competition by burros and exotic species. Managers should not allow livestock, exotics, or burros on desert bighorn sheep ranges. Under normal circumstances, coexistence is not possible. If other species are already present, the only solution that favors desert bighorns is to remove the other animals.

Research Recommendations

More information is needed on the relations between deer and desert bighorn sheep in natural and altered habitats. Jones (1980) and Halloran and Deming (1958) suggested that deer may successfully compete with bighorns for forage and water but specific data are lacking. In some ranges such as the Santa Catalina Mountains in Arizona, fire has been recommended as a tool to create bighorn habitat; however, interactions between sheep and deer on burns have not been documented. Research of interspecific interactions on altered habitats (e.g., burns, waterholes) would be valuable.

Because the influence of predators, particularly mountain lions, on sheep populations in southern ranges is limited, little remedial action seems necessary. However, managers should be alert for problems that may develop when sheep populations are low, the range is in poor condition, or water supplies are extremely limited.

Diseases and parasites of species not sharing range with bighorn sheep pose little threat, even though bighorns may be susceptible. When barriers are removed by habitat changes, and populations mix or exotic species are introduced, there is potential for great harm. Any study of sympatric ungulates should include investigations of their diseases and parasites.

Synopsis

Many biologists have studied desert bighorn sheep, and there is a wealth of literature available on their life history, behavior, and management. The desert bighorn apparently is not adapted physically or physiologically to a desert environment to the extreme extent of many other desert ungulates. Thus, there is need for more complete physiological and anatomical descriptions of the mechanisms of temperature regulation and water retention that permit this species to use arid habitat. The desert bighorn apparently adapts behaviorally to the extremes of heat and water shortage, but more should be learned of this behavior to guide management.

Man's activities are increasing the pressure on desert bighorn populations. The combined effects of habitat fragmentation, degradation, and alteration added to competition from other ungulates will continue to stress

desert bighorns. Attempts to offset a dwindling resource by reintroductions, population augmentations, habitat manipulation, and water development introduce new variables to assess. Mixing stocks of bighorns that have been geographically and possibly genetically isolated may explain why some populations are now more susceptible to certain diseases and parasites. Adding water to previously arid habitats may allow other ungulates to encroach and overutilize the food resource. Recently increased emphasis on management provides the opportunity to gather more information about the health of herds, but these data will only be useful if their collection is planned. Any management activity should include the mechanism for evaluating the results. Enough descriptive information is now available that research should be designed to test experimental hypotheses.

The various agencies that manage bighorn sheep should establish research priorities and integrate their activities, not only to avoid duplication, but also to ensure that correct answers are found. In this guide, we have tried to identify some priorities for current management and research. Implementation of comprehensive, multi-agency programs is now needed.

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Appendix A. Visually Assessing Physical Condition of Bighorn Sheep.

Although physical condition of wild ungulates will vary in relation to season, a departure from the normal variation usually indicates something is amiss. The problem could be disease, malnutrition, or something else. The opportunities to obtain samples, weights, or indices of condition from animals in hand are usually very limited—limited either in number or when the sample can be taken (i.e., from hunter-killed males or during sporadic translocating operations).

Recognizing the need for estimates of physical condition and the difficulties of getting the normal indices, McCutchen (1985) modified the Riney (1960) technique of visually assessing physical condition of ungulates. As subcutaneous fat reserves are used, the rounded appearance of the rump becomes more angular. Eventually, as physical condition worsens, muscle tissue is catabolized, which accentuates the concave appearance of certain portions of the body. McCutchen's (1985) paper best describes the three condition classes.

> The illustrations of Riney's (1960) ungulate condition classes presented only the lateral view. At Zion, a posterior view was often helpful in more accurately placing an animal into a condition class. Thus both lateral and posterior views are provided for bighorn sheep.
>
> Three condition classes (good, medium, and poor) were developed for desert bighorn at Zion (Fig. 1). A sheep in good condition (Fig. 1A) laterally shows lines of roundness from (a) the pin bone (*Tuber ischii*) region to (b) the posterior area of the sacrum. Generally the back is straight or nearly so. From a posterior view (Fig. 1B), the animal exhibits roundness of the back and rump with no depressions or angulations. Bighorn classed in medium condition, from the lateral view (Fig. 1C), have angles appearing at the pin bone (a) and at the posterior processes of the sacrum (b). Posteriorly, a bighorn in medium condition (Fig. 1D) exhibits truncation at the top of the back and angulation at the edges where the top of the back joins the sides. As condition further declines, a depression is often visible as a line (c) above the tail. As bighorn degrade to poor condition, the areas above and below the pin bone (a) collapse and become concave (Fig 1E), giving the pin bone area a pointed appearance. Bighorn in this class frequently show nearly vertical femur lines (d) and lines along the lateral processes of the spine and tail (e). From a posterior view (Fig. 1F), animals in poor condition exhibit boniness in the backbone area, the hip bone (*Tuber coxae*) area, and the femur/sacrum junction. The flesh appears to be draped in concave folds on the body.

Less objective indications of poor condition include humped posture, depressed flanks, lowered head and neck, and drooped ears (McCutchen 1985). McCutchen (1985) also discussed the physical appearance of different sex and age classes in response to the annual cycle and to disease.

Because internal measures of physical condition (kidney fat, subcutaneous fat, bone marrow, etc.) are difficult to obtain, we encourage using the visual assessment technique. Wildlife managers should systematically record condition class whenever they observe bighorn sheep. When carcasses are available, the internal indices of physical condition should also be calculated.

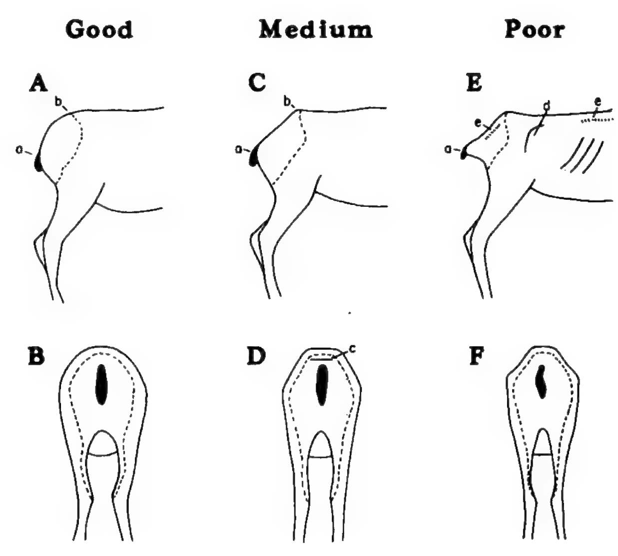

Figure A-1. (Referred to as Figure 1 in the quoted material). Bighorn condition classes established from desert bighorns, Zion National Park, Utah (McCutcheon 1985) A and B—good condition; C and D—medium condition; E and F—poor condition.

Appendix B. Collecting Blood from Bighorn Sheep.

As Bagley and Bunch (1980) noted, many physiological, genetic, and disease conditions can be assessed or monitored by analyzing blood of living animals. They described techniques and equipment to collect and store blood. The following information has been extracted from their paper. Anyone contemplating collecting blood for the first time should consult a veterinarian familiar with research and management goals. Thereafter, managers should refresh their memories by referring to Bagley and Bunch (1980).

Drawing Blood from Bighorn Sheep

Generally, either whole blood or serum (whole blood minus the clot) is needed for various analyses. Tests for many diseases and blood chemistry use serum, whereas for tissue culture, chromosomal studies, and cell counts, whole blood is needed. Whole blood is fragile and should be treated gently.

Restraining the Animal

The animal to be sampled must be restrained. Methods must be well planned before trying to collect blood. Bagley and Bunch (1980) emphasized that preparation and planning before the actual sampling is paramount. Collecting blood stresses animals; thus, managers should be cautious.

Preparing the Site of the Collection

Dirt, burrs, debris, and other foreign material should be removed from the puncture site. Hair can be clipped or moistened with alcohol or water to make the jugular vein more obvious. It is most easily reached in the upper one-third of the neck lying in the groove on either side of the trachea. Further down the neck, heavier muscles cover it.

Collecting Whole Blood

To keep the blood from clotting, an anticoagulant (such as heparin, sodium citrate, or EDTA) should be used. A sterile, disposable 10–12 mL syringe with a 65–75 mm (2 1/2–3 in.) 18-gauge needle will usually be adequate. Rinse the inside of the needle and syringe with the anticoagulant and let it dry. (Before selecting the anticoagulant, check with the laboratory analyzing the blood. Some anticoagulants interfere with various tests). Locate the jugular vein by restricting the return flow with finger pressure in the upper one-third of the neck. When the vein distends (in a few seconds), tap it with your finger to verify that it is a vein. Insert the needle quickly and firmly, anticipating that the animal may struggle. By using the needle without the syringe attached, you can quickly release it when the animal struggles. The weight of the needle itself won't cause it to fall out. If the blood flows evenly, the needle is in the vein. If no blood flows, the needle may be clogged or you missed the vein. If blood spurts—in the artery—withdraw it slightly. The artery is deeper than the vein, and the needle may have gone through the vein and into the artery. Slight withdrawal may correct the location. If not, withdraw it, check to see if the needle is plugged and try again at a slightly different place.

Once the needle is in the vein either attach the syringe or just let the blood flow into the collection container (e.g., a vial, or "vacutainer,"). Withdraw 10–50 mL, depending on your needs. *Gently* mix the blood with the anticoagulant by slowly inverting the container or swirling the blood. If the blood was collected with the syringe, remove the needle before emptying the syringe. Forcing the blood through the needle may rupture fragile red cells and this will interfere with many tests.

Collecting Serum

Use the same procedure except do not use an anticoagulant. Let the blood stand in an upright vial at room temperature (21°–24°C; 70°–75°F) for about an hour. In the field, you may have to use a cooler to get the temperature within that range. Do not jostle the sample (as carrying in a backpack will do) prior to removing the serum from the clot. When the clot has formed (centrifuge the vial if possible), draw off the straw-colored, clear serum with a clean syringe and needle, and place it in a sterile vial. The serum itself is not harmed by shaking. It also may be frozen for storage and shipment. Check with your laboratory for specific instructions.

Care of Samples

- You may freeze serum but *not* whole blood. If in doubt, merely refrigerate the samples.
- Avoid heat.
- Divide serum samples into 1–3 mL subsamples.
- Store samples in glass, plastic, or polyethylene screw-top or snap-cap vials. Identify each sample or subsample with a permanent label.

Appendix C. Age Classification of Desert Bighorn Sheep.

The age of desert bighorn sheep often can be determined from horn size, shape, and annular rings (Table AC-1). Figures C-1, C-2, and C-3 illustrate the use of horns to classify and age sheep.

Table AC-1. *Horn characteristics used to age desert bighorn sheep (Hansen and Deming 1980).*

Age	Horn characteristic
< 7 d	No horns.
1–2 mo	Horns just appearing above the tufts of hair; color dark blue-gray.
3 mo	Horns 25–40 mm (1–1.5 in.) above hair.
4 mo	Horns 50–75 mm (2–3 in.) in male; 25–38 mm (1–1.5 in.) in female.
5 mo	Horns 75–100 mm (3–4 in.) in male; 50–75 mm (2–3 in.) in female.
6 mo	Horns 100–150 mm (4–6 in.) in male, thick and bulky; 75–100 mm (3–4 in.) in female, slender.
8 mo	125–200 mm (5–8 in.) in male, thick; 100–125 mm (4–5 in.) in female, slender.
12 mo	Horns 200–305 mm (8–12 in.) in male, appearing much like adult ewe horns, but thicker at the base and still a blue-gray color, in contrast to the light brown of the adult ewe; 125–178 mm (5–7 in.) in female, thin and sharp-pointed.
18 mo	Horn growth stops or slows to the point where a depression or series of them are left on the horn.
30 mo	Horn growth may stop two or three times during this and the next rut period. This often leaves one prominent and one or two less prominent rings on the horn.
3.5–7.5 yr	Horn growth stops each rut period and forms a deep dark ring. These rings are separated by a portion of light brown horn. The distance between each ring is narrower each year, until only about 25 mm (0.5 inches) separates the 7.5-yr ring from the 8.5-yr ring.
8.5–16 + yr	This portion of new horn is usually covered by hair in the live animal, and it is difficult to determine how many rings are present. Rings may be 3.2 mm (0.125 inches) or less apart. It is almost impossible to age ewes beyond 7.5 yr because the rings are usually so close together.

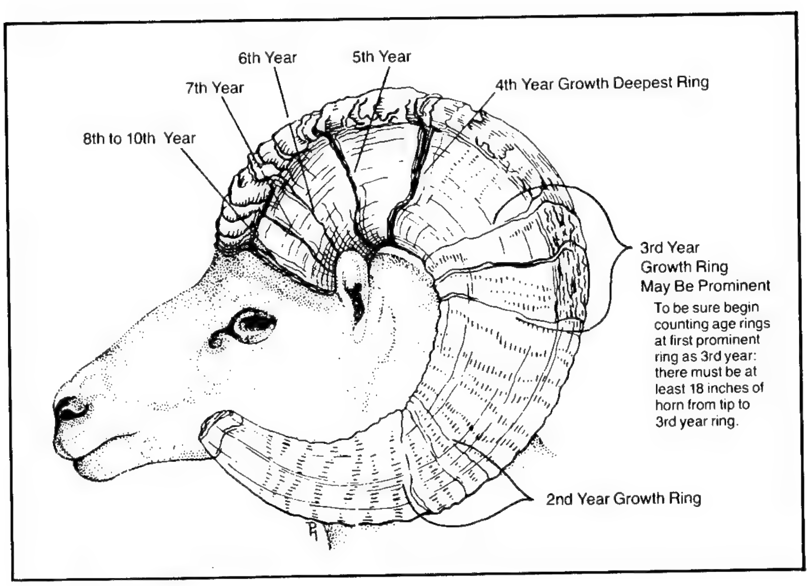

Figure C-1. Horn ring method of aging desert bighorn sheep (Reprinted by permission from the University of Arizona Press, Tucson [Hansen and Deming 1980. Growth and development. Pages 152–171 *in* G. Monson and L. Sumner, eds. The desert bighorn. University of Arizona Press, Tucson.]).

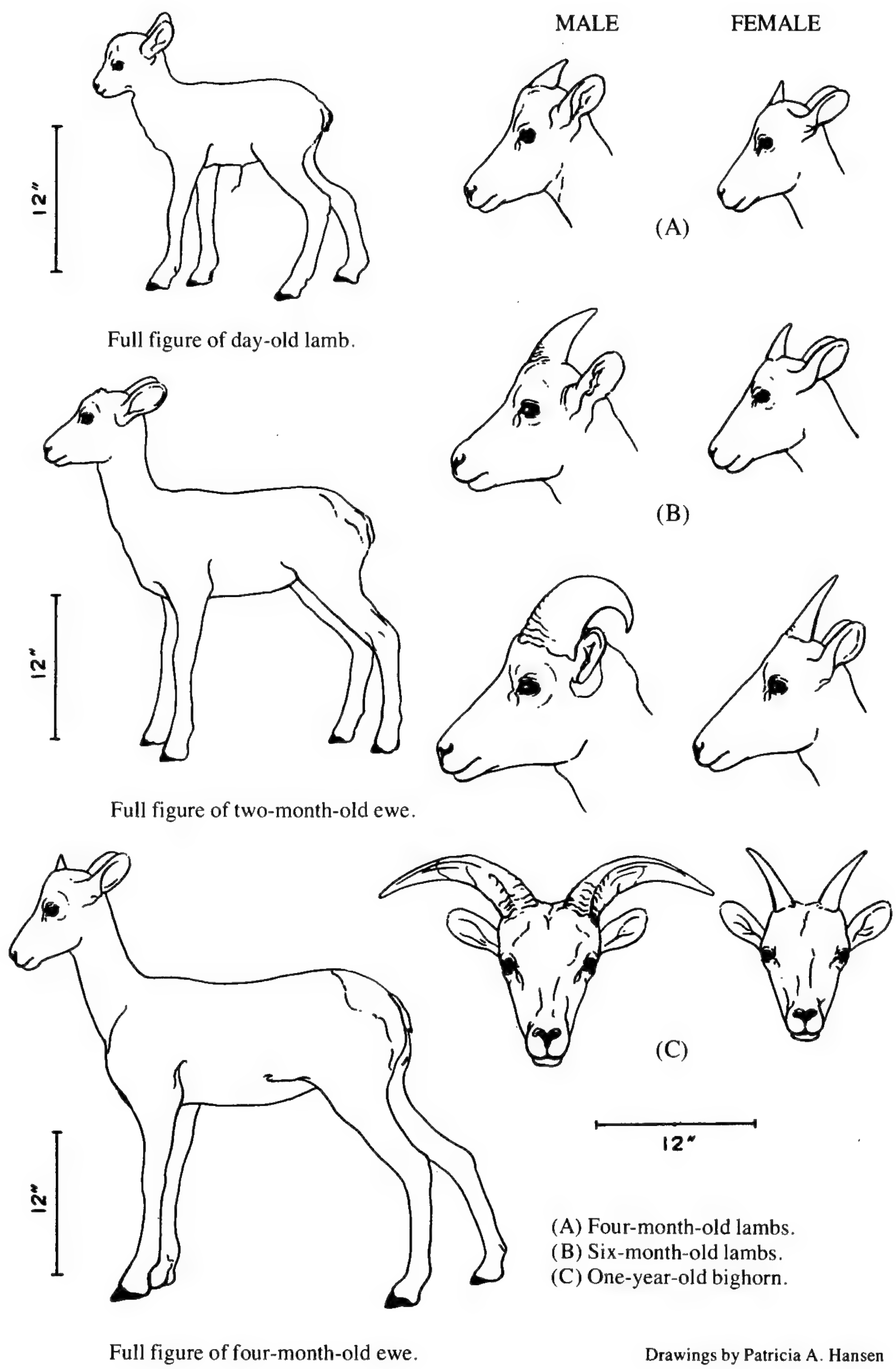

Figure C-2. *Top left* = Full figure of day-old lamb. *Middle* = Full figure of 2-mo-old ewe. *Bottom* = Full figure of 4-mo-old ewe. *A*. Heads of 4-mo-old lambs. *B*. Heads of 6-mo-old lambs. *C*. Heads of 1-yr-old adults (Reprinted by permission from the University of Arizona Press, Tucson [Hansen and Deming 1980. Growth and development. Pages 152–171 *in* G. Monson and L. Sumner, eds. The desert bighorn. University of Arizona Press, Tucson.]).

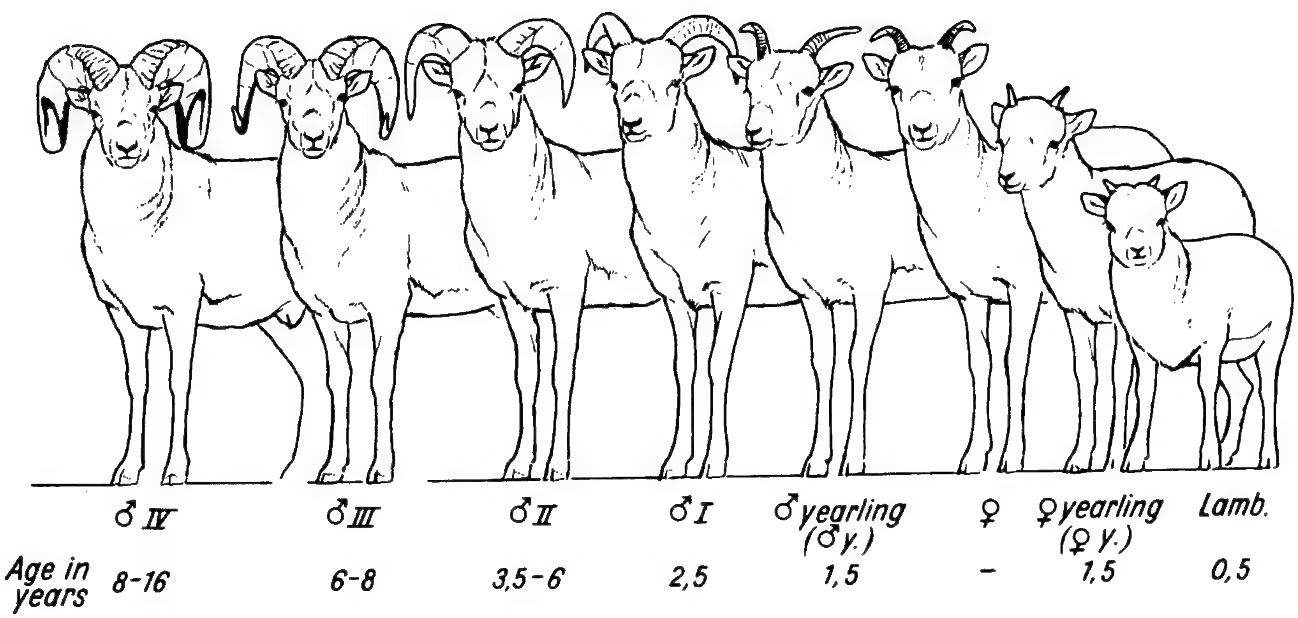

Figure C-3. The sex and age classes of bighorn sheep. Note that the animals form a cline in body and horn size, and the adult female is very similar in external appearance to the yearling ram (Reprinted by permission from V. Geist [Geist, V. 1968. On the interrelation of external appearance, social behaviour, and social structure of mountain sheep. Zeit. Tierpsychol. 25:119–215]).

Appendix D. References to the Construction and Development of Water Catchments for Desert Bighorn Sheep.

Water development is a management activity of all agencies responsible for desert bighorn sheep. This list of selected references is included for the convenience of interested wildlife managers.

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Wilson, L. O. 1977. Guidelines and recommendations for design and modification of livestock watering developments to facilitate safe use by wildlife. U.S. Bur. Land Manage. Tech. Note 305. 27 pp.

Yoakum, J., W. P. Dasman, H. R. Sanderson, C. M. Nixon, and H. S. Crawford. 1980. Habitat improvement techniques. Pages 329–403 *in* S. D. Schemnitz, ed. Wildlife management techniques manual, Fourth ed. The Wildlife Society, Inc., Washington, DC.

Appendix E. Vegetation Sampling.

Vegetation associations in desert ecosystems can be simple, but they can be difficult to describe. A first step is to establish the major associations based on two or three dominant perennial plants. ("Dominant" refers to plants that are visually dominant—palo-verde, *Cercidium* spp.; saguaro *Carnegiea gigantea*; creosotebush, *Larrea tridentata*; or mesquite, *Prosopis* spp.) When one is interested in describing associations more specifically, the line-intercept technique is helpful. Information about species composition of an association can be obtained from data on the numbers, linear extent, width, and frequency of occurrence of individuals of different species intercepted by a series of line transects that pass through the association. All standard vegetational measurements may be obtained by this technique, and other variables may be evaluated, such as thermal cover (the amount of vegetation that can provide shade to an adult sheep ≥ 1 m tall).

Procedure

Random sampling points are important in any sampling scheme. Researchers establish a baseline along one side of the area involved. A series of points along this baseline are then selected by a random or stratified random procedure. These points can be used as starting points for transects through the area. Random points can also be selected by pacing any number of steps along a randomly selected route.

Use a 15–30 m measuring tape to lay out a line transect. Use a tape-measure scale to subdivide the line transect into intervals of any size to determine frequency. The tape-measure scale also provides a means of measuring the length of the segments of transect intercepted by individual plants. Meter sticks or short tape measures are needed to measure other plant size characteristics.

Plants that are intercepted by the transect line and that underlie or overlie the line should be recorded. When the line passes through a plant, two measurements should be recorded in a table (Figure E–1): the length of the transect line intercepted (I) and the maximum width of the plant perpendicular to the transect line (M). In the table, data for different transect intervals should be placed in different columns; the length of transect segments overlying bare ground should be measured and recorded in the same manner.

In summarizing the sampling data, total number of individuals encountered (N), total of intercept lengths (ΣI), number of transect intervals in which species occurred, and total of reciprocals of maximum plant widths (Σ1/M) should be determined for each species and recorded in a second table (Figure E–2).

With these values the density and relative density of vegetational composition can be determined:

$$\text{Density} = \sum \frac{I}{M} \, \frac{\text{Unit area}}{\text{Total transect length}}$$

$$\text{Relative density} = \frac{\text{Density for a species}}{\text{Total density for all species}} \times 100$$

The unit area in this calculation is simply the size of the area (in the same units as plant width and transect length) on the basis of which density is to be expressed. For example, if plant widths and transect length are measured in inches, the unit area value in the equation is the size of the area, in square inches, for which the density value will be stated. A complete explanation and derivation of the density calculation above is given by Strong (1966).

Dominance (% of ground cover) is calculated with the following equations:

$$\text{Dominance} = \frac{\text{Total of intercept lengths for a species}}{\text{Total transect length}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total of intercept lengths for a species}}{\text{Total of intercept lengths for all species}} \times 100$$

Frequency values are calculated from the following equation:

$$\text{Frequency} = \frac{\text{Number of intervals in which species occurs}}{\text{Total number of transect intervals}} \times 100$$

Frequency is somewhat misleading because the chance of a species being recorded in a given transect interval is related both to the size of the individual plants and to the abundance and distribution of the species. In calculating relative frequency, this may be taken into account. A weighting factor ($F = \frac{\Sigma I/M}{N}$) can be derived and used to calculate a weighted frequency as follows:

$$\text{Weighted frequency} = (F)\left(\begin{array}{c}\text{Number of}\\ \text{transect intervals}\\ \text{in which species occurs}\end{array}\right)$$

$$\text{Relative frequency} = \frac{\begin{array}{c}\text{Weighted frequency}\\ \text{for a species}\end{array}}{\begin{array}{c}\text{Total of weighted}\\ \text{frequencies for all species}\end{array}} \times 100$$

From these values an importance value can be calculated:

Importance value = Relative density + relative dominance + relative frequency.

An estimate of the total percentage of the ground surface covered by vegetation may be obtained by totaling cover percentages if measurements of intercept distances were taken in a nonoverlapping manner. If intercept measurements overlap owing to the sampling of individuals belonging to different strata, total plant coverage must be obtained by the formula:

$$\text{Total coverage} = \frac{\begin{array}{c}\text{Total transect length}\\ -\text{ total bare ground}\end{array}}{\text{Total transect length}} \times 100$$

Additional information about line intercept techniques may be obtained from the following literature:

Anderson, K. L. 1942. A comparison of line transect and permanent quadrats in evaluating composition and density of pasture vegetation of the tall grass prairie type. J. Am. Soc. Agron. 34:805–822.

Bauer, H. L. 1943. The statistical analysis of chaparral and other plant communities by means of transect samples. Ecology 24:45–60.

Canfield, R. 1941. Application of the line interception method in sampling range vegetation. J. For. 39:388–394.

McIntyre, G. A. 1953. Estimation of plant density using line transects. J. Ecol. 41:319–330.

Strong, C. W. 1966. Improved method of obtaining density from line-transect data. Ecology 47:311–313.

Intercept and Maximum Plant Width Values for Plants of Different Species Encountered in Line Transect Sampling.

Date ______________ Locality ____________________ Stand (type or number) ________________________________

Observer name ____________________________________ Interval length ________________________________

Species	Interval # ____		Interval # ____		Interval # ____		Interval # ____		Interval # ____		Interval # ____		Interval # ____		Interval # ____		Interval # ____		Interval # ____	
	I	M	I	M	I	M	I	M	I	M	I	M	I	M	I	M	I	M	I	M

Figure E-1. Intercept and maximum plant width values for plants of different species encountered in line transect.

Summary of Vegetational Measurements Obtained by the Line Intercept Technique.

Date ____________ Locality ____________ Stand (Type or Number) ____________

Observer Name ____________ Interval Length ____________ Number of Intervals ____________

Species	N	Σ1	Intervals in which Recorded	Σ1/M	Density per ____	Relative Density	Dominance	Relative Dominance	Frequency	Relative Frequency	Importance Value

Figure E-2. Summary of vegetational measurements obtained by the line intercept technique.

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13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This guide summarizes pertinent literature on four topics of desert bighorn sheep ecology and management: (1) their water requirements and adaptations are compared with those of other desert-dwelling ungulates; (2) the effects of human activities such as mining, poaching, hunting, ranching, hiking, and urban encroachment are discussed; (3) diseases and disease control, specifically scabies and desert bighorn sinusitis, are reviewed; and (4) the relation of bighorn sheep to other resident wildlife is addressed. Recommendations for management and research are included in each section. Finally, appendixes provide information on how to assess physical condition, collect blood, classify the age of sheep, construct water catchments, and sample vegetation.

17. Document Analysis a. Descriptors

Desert bighorn sheep, life history, ecology, population dynamics, desert, disease, species interactions, disturbance, transplantation, range management

b. Identifiers/Open-Ended Terms

Arizona Cooperative Fish and Wildlife Research Unit

c. COSATI Field/Group

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